DIGITAL MODULATION AND SHIFT KEYING

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims the benefits of U.S. provisional patent application No. 60/430,459 filed December 3, 2002, which is hereby incorporated by reference.

TECHNICAL FIELD

[0002] The invention relates to digital communication, or more particularly to the modulation of a carrier with digital information.

BACKGROUND

[0003] Digital modulation of signals is a necessary component of communication of digital information across a network. Generally, the object of modulation is efficient transmission of information across a channel. Modulation operates by keying shifts in analog characteristics in response to the encoded modulation input. Modulation in its simplest form shifts frequency, amplitude or phase.

[0004] A sequence of modulated signals may give rise to sharp discontinuities of slope in the modulated carrier. Such discontinuities are associated with high harmonics. This is bandwidth intensive. Such use of bandwidth may be incompatible with efficient communication system design. Further, random occurrence of discontinuities within the communication may add bandwidth without introducing ancillary benefits such as reliable synchronization.

[0005] Accordingly, it is an object of the present application to obviate or mitigate some or all of the above disadvantages.

SUMMARY

[0006] According to the present invention, there is provided a method of modulating a carrier with digital information having a series of datums represented in a plurality of symbols, said method comprising:

selecting a first number of half-periods of a first phase distinguished carrier signal for representing a corresponding symbol of a first one of said datums;

selecting a second number of half-periods of a second phase distinguished carrier signal for representing a corresponding symbol of the datum following said first datum;

determining at least one matching carrier signal having a third number of half-periods of a format to conform to a transition of said first phase distinguished carrier signal to said second phase distinguished carrier signal; and

sequentially arranging said first number of half-periods of a first phase distinguished carrier signal, said third number of half-periods of said matching carrier signal and said second number of half-periods of said second phase distinguished carrier signal.

BRIEF DESCRIPTION OF THE FIGURES

[0007] Embodiments of the invention will be described by way of example only with reference to the accompanying drawings, in which:

[0008] Figure 1 is a table of datum representation in digital modulation.

[0009] Figure 2 is a table of datum representation in digital modulation.

[0010] Figure 3 an example of a Phase Shift Keying (PSK) modulated wave.

[0011] Figure 4 is a table comparing a Yaw Shift Keying (YSK) enhanced version of PSK to un-enhanced PSK.

[0012] Figure 5 is a comparison of two matching signals: one higher and one lower frequency.

[0013] Figure 6 is a diagram of a YSK modulation apparatus.

[0014] Figure 7 is a timing diagram associated with the apparatus of figure 6.

[0015] Figure 8 is a timing diagram illustrating the implications of non-coherent detection.

[0016] Figure 9 is a diagram of a YSK demodulation apparatus.

[0017] Figure 10 is a diagram of another embodiment of a YSK demodulation apparatus.

[0018] Figure 11 is a diagram of a YSK demodulation apparatus illustrating one frequency filtering method.

[0019] Figure 12 is a schematic diagram of a shaped RYSK signal.

DETAILED DESCRIPTION

[0020] Digital information is composed of a series of datum. Each datum is represented by one of n symbols. Typically such symbols are, themselves, a series of m binary digits. In this way a series of m binary digits may form up to 2^m symbols i.e. $n <= 2^m$. Referring to figures 1 and 2 (prior art) we have tables of two such representations **80** and **90**. In the first representation **80**, the possible datum of digital information **100** are binary (A,B) and represented by two possible symbols **110**. In the second representation **90**, the possible symbols of digital information **120** are quaternary and represented by four possible symbols **130** (A,B,C,D).

[0021] Modulation is a variation of a carrier wave in response to a modulating wave. Modulation may involve a variation of one or more aspects of the carrier. Phase Shift Keying (PSK) modulation is a digital modulation format. Referring again to the tables of figures 1 and 2 we see the PSK carrier signals **140, 150,** respectively, of the PSK modulated wave as associated with the corresponding symbols **110,130,** respectively, they represent, and the corresponding possible datums of digital information **100,120,** respectively. These different carrier wave signals **140** and **150,** have identical frequency and amplitude, but different phase. In this way they are phase distinguished. The signals **140** of the first table are antipodal (180 degree phase shifted). The signals **150** of the second are 90 degree phase shifted. It is traditional that the carrier itself be sinusoidal. PSK has a constant envelope, giving it the desirable quality of imperviousness to non-linearity. Referring to figure 3 (prior art)we have an example of a PSK modulated wave **160** (composed of signals **165**), the series **170** of digital symbols **175** the signals represent, and the digital information **180** used to modulate it (composed of the datums **185** that correspond to symbols **175**). This example uses the representation **80** of figure 1. In PSK modulation, it is convenient, but not necessary, for each modulated datum of information to be signaled with one, or multiple, half period(s) of carrier wave i.e. an

integral number of periods. To simplify the generation of the modulated signal when a Digital to Analog Converter (DAC) is used to convert a table of values, it is convenient to make use of waveforms that include integral number of periods. When the number of periods is a non-integral number, the transmission of the fraction of period of the carrier waveforms at the end of each symbol causes the phase of the signal to vary from one starting point of a symbol to the other. An integral number of period eases the waveform generation since it is sufficient to repeatedly transmit the same waveform to a sine wave with no phase discontinuities. If an integral number of half-periods is used, generation of a continuous wave is as simple as for the integral case as long as the polarity of the waveform is toggled from one transmission to the other when this number is odd. For an even number of half-periods, we have an integral number of periods.

[0022] For simplicity, we have illustrated one integral number of periods per datum. Those skilled in the art will understand the other possible PSK modulation schemes involving M-ary (binary, tertiary, etc.) data or use of differential shift keying (symbol determined by change of phase rather than phase.)

[0023] In a traditional PSK modulated signal, as per figure 3, sharp discontinuities of slope **190** may arise at the point of transition between successive signals. The resulting high harmonics are undesirable in communication systems. One aspect of the invention is a method of modulation in which two sets of symbols are employed. The first (data) symbol set is information oriented. The symbol sets are interleaved, and the second (matching) symbol set is chosen to avoid sharp discontinuities. Referring to figure 4 such a method, hereinafter referred to as Yaw-Shift Keying (YSK), is discussed as applied to PSK.

[0024] Figure 4 is a table **200** comparing YSK enhanced version of PSK to PSK. Column one shows all the permutations of successive digital information **210** to be modulated for the modulation representation **80**. Column two is the corresponding PSK Modulated carrier. The transitions from preceding carrier waves **220** to successive carrier waves **230** may give rise to discontinuities of slope **190**. Column three shows possible corresponding YSK enhanced modulation. In this enhancement, similar to PSK:

- each symbol of the digital information **210** is represented, in part, by a different carrier wave signal, **220, 230**; these carrier wave signals **220,**

230 have identical frequency and amplitude, but can have different phase. (phase distinguished);

- and the carriers themselves are sinusoidal.

[0025] However, in the inventive method, between two successive carrier wave signals (data) a matching carrier signal (support) **240** is inserted. Such a wave signal:

- conforms to (i.e. has no discontinuity or discontinuity of slope), at its beginning, the preceding carrier wave, **220**, and at its end, the successive carrier wave, **230**;
- and has duration equal to an integral number of carrier 1/2 sinusoids (one is illustrated in the table **200**).

[0026] Note that matching waves of both higher and lower general frequency (than the carrier) are shown. Either of these waves are compatible. This implementation (discontinuity reduction) reduces bandwidth. Other implementations could use waveforms that facilitate synchronization (e.g. Spikes or high frequency burst for carrier recovery as for the color burst in TV. signals.)

[0027] In YSK enhancement, modulation is staggered between waveforms (like the carrier waves **220, 230**) devoted to transporting information, and waveforms (like the matching carrier **240**) devoted to easing recovery (bandwidth control, synchronization).

[0028] Both these examples use a single carrier wave period for the carrier waves **220, 230.** However, for ease of generation, one can envision using any integral number of ½ periods for YSK enhanced PSK, as is the case in PSK. In cases where generating fractional period phase shifts is not an issue, the number of periods is, in fact, immaterial.

[0029] For a given representation (e.g. representation **80, 90**) the set of transitions (for all permutations of preceding **220** and successive **230** carrier signals) will require matching signals **240** for each transition. Where the successive waves are identical, a third identical wave is a simple choice for the matching carrier signal **240**. (provided bandwidth reduction is the goal. A totally different waveform might be preferred if ease of synchronization is the priority.) In the table **200** we have shown a shaped waveform for the matching carrier signal **240** where the successive waves **220, 230** are antipodal.

[0030] This is not to imply the shown matching waveforms **240** are the only choices. One possible basis of matching wave signals **240** is sinusoidally modulated

quadrature carriers from which linear combinations may be derived to satisfy the various transitions. Such signals are used in minimum-shift keying (MSK). One advantage of using such particular sinusoids is they produce an overall signal that is phase continuous. To satisfy this criteria, the matching signals **240** do not give rise to a discontinuity or change in slope that substantially negatively influences the communication system. Another advantage of using MSK signals relies in the fact that it involves the minimum frequency spacing that leads to a signal which is phase continuous. Since this method represents the maximum reduction in bandwidth, this particular shaping of the matching signals is referred to as Reduced Yaw Shift Keying (RYSK). Note that MSK is applicable only if the matching signal differs by ½ period from the signaling waveform In other cases a broader spectrum results. As it can be seen from figure 4, the matching carrier signal **240** may be of higher or lower frequency than the carrier waves **220, 230**. Thus the average frequency of the YSK signal may be equal to the frequency of the carrier waves **220, 230**. Instantaneously, it may drift from this center frequency to higher or lower values in a manner that depends on the data symbol. Due to this frequency "yawing" that the present invention is termed "yaw shift keying" (YSK). In regard to the signal's bandwidth, it is an advantage to have matching signals **240** of higher and lower frequency than the center frequency (of waves **220, 230**) since it leads to a average spectrum of the signal which is symmetrical when one support waveform is used as often as the other. Other implementations may make use of support waveforms that are both of higher, or lower, frequency than the frequency of the signaling waveform depending on the desired spectrum of the signal. More than two support waveforms can also be considered in order to spread the signal's energy across a wider bandwidth.

[0031] In the example **250** of figure 5, waveforms are used for the matching signals **240a** and **240b** that respectively, are composed of substantially, lower and higher frequency components than the base carrier frequency of the preceding and successive carriers **220, 230**, respectively. It is possible to allow for multiple satisfactory matching wave signals **240** (such as examples **240a** and **240b**) per individual transition, and to chose between them on a transition by transition basis . For a given transition, one matching signal **240** of the possible satisfactory matching wave signals may then be chosen. In this manner, the frequency side-bands of the carrier may be balanced by

alternating between a higher and lower spectral matching signal **240**. This balancing is desirable. Alternatively, another information signal (based on the matching choice) may be superimposed upon the modulated carrier by deliberately choosing amongst possible matching signals **240**. In this sense, it is possible to interleave two sets of digital information in one phase continuous carrier. The first (communicated with signals including 220, 230) is phase encoded; the second (communicated with signals including 240) is frequency encoded.

[0032] It may be understood by one skilled in the art that the principles of YSK extend to other modulation formats. PSK is used here for illustration, but the idea could be applied to frequency or amplitude shift keying as well. The central principle is a modulated signal composed of interspersed matching signals between information, in such a manner as to maintain continuous phase.

[0033] Figure 6 is an apparatus **401** for generating the YSK modulation. The apparatus consists of a preceding symbol memory **405**, a matching signal lookup **415**, a carrier signal lookup **425**, switches **435**, and **445**, and summation unit **455**. The symbol memory **405** is input coupled to the input symbol port **400**, and the carrier/matching clock port **420**. The symbol memory **405** output is coupled to the preceding input of the matching signal lookup **415** via connection **410**. Matching signal lookup **415** is also coupled to a synchronizing clock port **430** and to the input symbol port **400** at the successive input. The carrier signal lookup **425** is input coupled to the input symbol port **400**, the synchronizing clock port **430**, and the carrier/matching clock **420**. Switches **445** and **435** are control coupled to the carrier/matching clock port **420** and its complementary port **421**, respectively. Switch **435** couples the matching signal lookup **415** output to a summation unit **455** input. Switch **445** couples the carrier signal lookup **425** output to a summation unit **455** input. The output of the summation unit **455** is the YSK modulation apparatus output **460**.

[0034] Figure 7 shows a signal operation example of apparatus **401.** The input symbol **500** is asserted on the input symbol port **400,** and must be valid as shown. The carrier/matching clock **520** is asserted on the carrier/matching clock port **420,** and must be valid as shown. The symbol memory **405** records the current input symbol **500,** on the rising edge of the carrier/matching clock **520** and asserts this information **510** on

connection **410.** Due to this, the matching signal lookup **415** has, at the falling edge of the carrier/matching clock **520,** access to the current input symbol **500** at its successive input and the preceding input symbol **500** at its preceding input. The matching signal lookup **415** with these signals along with synchronizing clock **530,** (via synchronizing clock port **430**) generates matching signals **565** in accordance with the YSK method q.v. The carrier signal lookup **425** has access to input symbol **500,** the carrier/matching clock **520**, and the synchronizing clock **530.** These allow it to generate carrier signals for the appropriate number of periods of carrier. This example shows 3 carrier periods and 1 matching period. The switches **445, 435** are governed by the carrier/matching clock **520** (via the carrier/matching clock port **420** and its complementary port **421**). Along with the summation unit **455**, the switches **445, 435**, merge the output of the lookups **415, 425** to produce a single YSK wave **560** at the YSK modulation apparatus output **460.**

[0035] Those skilled in the art will understand that YSK may be coherently detected with standard means i.e. where there is no question of synchronization between modulation and demodulation, the portion of the YSK wave containing the information may be directly demodulated. In the case non-coherent demodulation, however, YSK poses specific challenges.

[0036] Referring again to the examples of YSK modulated carrier signals **250** of figure 5, efforts to demodulate a carrier signal, **220,230**, are complicated by the need to locate them amongst the matching signals **240a, 240b.**

[0037] Figure 9 illustrates an apparatus **900** for demodulating YSK signals. A YSK signal input **905** is input coupled to a switch **910**. The switch **910** is output coupled to a support demodulator **920** and a data demodulator **940**. A synchronizer **930** is input coupled to the support demodulator **920** and output coupled to the control terminal of the switch **910**. A Clock output **950** and data output **960** are coupled to the synchronizer **930** and data demodulator **940**, respectively. There is a need to de-interleave the matching signal (support) **240** and carrier signal (data) **220,230** before attempting to recover the information. When the reception starts, a switch **910** is in the position that allows the signal to reach the support symbol demodulator **920**. This demodulator triggers the synchronizer **930** each time it detects an incoming matching signal **240**. The synchronizer **930** then activates the switch **910** at the appropriate time in order to make carrier signal(s)

220, 230 reach the data symbol demodulator **240** for the duration of one data signal **220, 230**. At the same time, the synchronizer **930** generates a clock signal (on clock output **950**) that indicates when an information symbol is available at the data output **960**.

[0038] The architecture shown in figure 9 is not the only one that may be used to demodulate YSK signals. Referring to figure 10, there is shown an alternate embodiment of a demodulation apparatus **1000**, consisting of matched filters **1010**, output coupled to a decision making circuit **1020**, and input coupled to a synchronizer **1030** (which is in turn input coupled to the decision making circuit **1020**). Data output **1040** is coupled to the decision making circuit **1020**, clock output **1050** is coupled to the synchronizer **1030**. This simplification of the demodulator's architecture is possible if the waveforms that represent the datum are selected having this in mind i.e. by selecting waveforms that are orthogonal.

[0039] In this apparatus, some filters **1010** are built to "recognize" the support signals **240** and other filters **1010** detect the data signals **220, 230**. The decision making circuit **1020** is required to be able to identify which matched filter produces the largest output. The synchronizer **1030** is then fed with this information. The synchronizer **1030** analyses at what rate and for how long those matched-filters **1010** that are associated to the support signals **240** produce the largest output and then generates a signal that synchronizes the operation of every matched-filter **1010** with the timing of the incoming signals **220, 230, 240**. This improves the filter reliability and, in turn, helps the decision making circuit **1020** in identifying the origin of largest outputs. Working on more reliable information, the synchronizer **1030** can iteratively improve its timing signal. At the same time, the decision-making circuit **1020** sends to its data output **1040** the demodulated data signal. Aware of the time at which these symbols become available, the synchronizer **1030** also generates a clock signal on the clock output **1050.**

[0040] When the signaling waveforms that are used to implement YSK modulation are sine waves such as those used for binary phase shift-keying (BPSK), PSK or frequency shift-keying (FSK), the matched filters **1010** that are shown in figure 10 may be built with a mixer **1012** and an integrate & dump circuit **1014** as shown in figure 11. For such a circuit, the waveform that feeds a given mixer **1012** determines which signaling waveforms the associated filter detects. The integrate & dump circuit **1014** then

acts as a low pass filter. Provided that integration begins when a signal starts to come in and ends with the same signal, the integrate & dump circuit **1014** will produce a maximum output for a similar waveform. The output of the integrate & dump circuits **1014** corresponds to the cross-correlation value of the incoming signal with the waveform that drives the mixer. Figure 11 thus shows a classical cross-correlation-type demodulator adapted for YSK signals. For such a demodulator **1100**, the synchronizer **1030** controls at what time the integrate & dump circuit **1014** integrates in order for correct demodulation of YSK to take place.

[0041] In figures 10 and 11, the number of matched filters depends on the particular waveforms that are used to implement YSK. This number may be reduced if some of these waveforms share properties. For example, BPSK involves two waveforms that only differ because of their respective polarity. Thus, the outputs of the two matched filters that may be used to demodulate a BPSK only differ because of their polarities. Hence, to eliminate one of these matched filters, a decision-making circuit that processes the magnitude and sign of its input may be used.

[0042] It may be understood by one skilled in the art that using YSK involves certain trade-offs with respect to the length of the carrier waves **220**, **230** and the matching carrier **240**. Consider non-coherent demodulation of such a signal using a cross-correlation system (for implementation purposes, a desirable method): The sampling of the succeeding unrelated signals, may cause the response of the cross-correlator to be, for a limited period of time, a blend of both a response that depends on a preceding wave **220** and a matching wave **240**, or a matching wave **240** and a successive wave **230**. Depending on the length of the sampling period, it may be impossible, to guarantee a pure sample of the matching wave. In order to avoid circuit complexity in response to symbol interference, it is highly desirable to achieve a pure sample. This implies a shorter sampling period relative to the successive waves **220**, **230**. Reducing the length of the correlation sample itself is limited by the correlator ability to successfully identify the necessary signals: improvement here is governed by the state of cross-correlator art. Reducing the length of matching wave **240** may have a positive effect on demodulation, but having matching waves that are relatively too short can cause the bandwidth of the signal to be unnecessarily large. Furthermore, increasing the length of the data bearing

preceding and successive signals **220**, **230**, will have a deleterious effect on the data transfer rate. It can be understood from this that a compromise reflecting circuit complexity, data transfer rate, bandwidth, and data integrity is in order.

[0043] One aspect of the invention brings a solution to the problem of selecting the proper ratio for non-coherent demodulation. Consider a cross-correlator with a minimum effective sampling period of 1, and length L. We shall make N refer to the length of support bits (e.g: if that cross-correlator processes a given support –or interspersed- signal). If that cross-correlator processes a given signal of length N it produces L+N-1 values that depend on that signal. Therefore, the sampled correlation values must be spaced apart in time by at least L+N sampling intervals if situations for which both samples are affected by interspersed signals are to be avoided. On the other hand, the sampled correlation values must not be too far apart since this could lead to sampling of a correlation value that depends on two successive interspersed signals. By analyzing scenarios that involve various lengths of correlator and signals, it may be shown that the number of consecutive correlation values that only depend on a given data signal of M samples is M-L+1. This second condition means that the sampled correlation values must be spaced apart by at most M-L sampling intervals. Hence, we may write that the sampled correlation values must be spaced apart by a number of sampling interval T such that M-L>=T>=N+L.

[0044] This spacing must be larger than one to have more than one sampled correlation value per data bit. Therefore, the conditions that apply to the sampling of the correlation values also imply that the correlator's length must be smaller than the length of the data signal. Thus, the correlator of this embodiment only processes a part of each data signal at a time. To highlight this fact, we refer to it by saying that the embodiment makes use of partial-cross-correlators that computes partial cross-correlation values.

[0045] To preserve bandwidth, it is required to minimize the length of the data. Because we have a condition that states that the length of the data bits can be lowered down to the point for which we have M-L=T, we can conclude that the minimum length of the data bit can be such that M=T+L. Hence, for a given correlator length, the length of the data bits will be minimized if the sampling interval is kept to a minimum. Based on the conditions that are mentioned above, this is to say that we must have T=N+L. This

last result allow us to find that we need to have T=(M+N)/2 to preserve bandwidth. This condition indicates that it is only necessary to evenly sample the correlation values at a rate that corresponds to two samples per duration of a data signal, **220** and **230**, followed by a matching signal **240** to have pairs of sampled correlation values that each includes at least one value that only depends on a single data bit. If this condition is met, it is then only necessary to make use of classical time diversity combining or selection techniques to retrieve the information from the incoming bits. Combining techniques such as those that would involve comparison of the correlation values that form the pairs of value can then be considered as well as selection algorithm that would be based on identification of preamble sequences or detection of correct checksum values in the demodulated messages.

[0046] If the sampling rate of the correlation value is such that it is not required to demodulate the support signal, it becomes an advantage to reduce the length of the support signal to a minimum since this improves the overall throughput of the communication system. However, in order to have a YSK signal that can also be demodulated by circuits which take the support signal into account, it is better to keep the length of the support signal long enough to allow reliable demodulation of the support signal. The selection of a length for a bit can then be driven by a need to further simplify the design of the demodulators. Because it can be advantageous to have correlators that are all of the same length, one can think about using support signals that are of the same length as the correlators that are to be used to demodulate the data bits. In that case, the number of correlation values that depend on the support bits will be one per support bit. This will be desirable for those demodulators that do not demodulate the support signals and it will be acceptable for the other types of YSK demodulator that make use of the timing information carried by the support signals. Under these circumstances, the conditions given previously imply that N=L=(M+N)/4 which indicates that these types of demodulator will be able to demodulate a YSK signal for which the data signals are 3 times longer than the support signals. Different ratios can also be considered. What is important here is to select a ratio that allows the partial-cross-correlator to produce two or more partial-cross-correlation values per data signal in a way that ensures that at least one value per set depends only on the data signals.

[0047] A demodulation example in correspondence with these principles is shown in figure 8. Referring to this is a YSK modulated carrier **600**. Matching signals **620** are interspersed between long carrier signals **610**. The matching signals **620** are shown to be of constant amplitude for simplicity. Shaped waveforms described above could also have been used instead of the constant amplitude matching signals **620**. Referring to figure 12 that shows a shaped RYSK signal **1200**, shaped support waveforms **1210** are used when phase shifts are required and constant amplitude support waveforms **620** are selected otherwise. The shaped support waveforms **1210** have an amplitude that first decreases and later increases in a way that provides a narrower signal bandwidth; the amplitude variation being a result of the multiplication of the support sine waves with one period of a cosine signal which last the same as the support signal **1210**. Digital narrow band filtering techniques can also be involved in the design of the matching signal **1210** to provide additional bandwidth reduction. In the demodulation technique of the invention, the long carrier signals **610** are at least 3 times the duration of the matching signals. Demodulation sampling is not constant in this technique. Also in figure 8 sampling patterns are shown **680-687** in various states of alignment with the received carrier **600.** The sampling pattern consist of equal duration alternating periods of sampling **632, 636, 640, 644, 648, 652, 656, 660**, and waiting /not sampling **634, 638, 642, 646, 650, 654, 658** interspersed.

[0048] In any given sampling period **632, 636, 640, 644, 648, 652, 656, 660**, the received carrier **600** is detected using demodulation techniques common in the art (e.g. correlation). A carrier signal **610** will be successfully demodulated to a valid symbol by at least one of the sampling periods **632, 636, 640, 644, 648, 652, 656, 660.** Using the example of received carrier **670,** demodulation occurs in either sampling period **640** and/or **644** in any alignment **680-687**.

[0049] The demodulation results of pairs of sampling periods e.g. (**640** and **644**) both or either of which may be valid. In normal operating conditions, the symbol may be determined by the valid sample. Excessive noise may result in no valid signal or contradictory valid signals. In this case the system must acknowledge demodulation error. Where valid symbols are successively demodulated, there could be an uncertainty if these valid symbols corresponded to the same, or successive, signals. Therefore

demodulated symbols are, ideally, considered in relation to the second previous demodulated symbol e.g. sample **648** may be considered relative to **640** for differential signaling. This, in effect, results in two interleaved channels. One of these channels, if clock drift may be ignored, is likely preferable. Lastly, in order to determine which channel is preferable, the carrier **600** may include a preamble of several datums. Comparison of the decoded and expected preamble identifies the preferable channel.

[0050] A method of demodulation compatible with the aforementioned example is as follows: The incoming signals are sampled in predetermined periods. The samples are partially cross-correlated to detect data signals. A history of the correlations is used to generate data, and synchronization. Synchronization is used to control future sampling.

[0051] Although the present invention has been described by way of particular embodiments and examples thereof, it should be noted that it will be apparent to persons skilled in the art that modifications may be applied to the present particular embodiment without departing from the scope of the present invention.